भारतीय मानक
Indian Standard

IS 16368 : 2015
(Reaffirmed 2020)

थर्मोसाइफन टाइप सौर उर्जा चालित घरेलू हॉट वॉटर हीटिंग सिस्टम हेतू परीक्षण प्रक्रिया

Test Procedure for Thermosyphon Type Domestic Solar Hot Water Heating Systems

ICS 27.160;91.140.65; 97.100.99

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September 2015 **Price Group 7**

Renewable Energy Sources Sectional Committee, MED 04

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by the Renewable Energy Sources Sectional Committee, MED 04 had been approved by the Mechanical Engineering Division Council.

The Government of India has been promoting solar thermal systems and devices in the country by implementing wide ranging programmes. As a result, significant industrial infra-structure has been established for manufacturing of these systems and devices, and new design variations have also emerged over the period of time. The solar thermal industry is manufacturing different types of solar water heating systems and the government is implementing various programmes related to large-scale promotion and dissemination of this technology. This test procedure is envisaged for testing of the domestic solar water heating systems manufactured by the solar thermal industry. The test procedure would enable quality control of the solar water heating systems promoted and disseminated in the country.

The standard has been formulated to evolve a uniform test procedure for solar hot water systems, especially of domestic type, using flat plate collector or evacuated tubular collector. The standard is based on a draft test procedure developed at Indian Institute of Technology, Bombay under a Research and Development Project sponsored by the Ministry of New and Renewable Energy and further experiments conducted at Regional Test Centre, Devi Ahilya Vishwavidyalaya, Indore.

The composition of Committee responsible for the formulation of this standard is given at Annex E.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding of numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

TEST PROCEDURE FOR THERMOSYPHON TYPE DOMESTIC SOLAR HOT WATER HEATING SYSTEMS

1 SCOPE

This standard covers test procedure to evaluate thermal performance of domestic solar hot water systems, using flat plate collector (FPC) or evacuated tubular collector (ETC), working on thermo-syphonic flow of water under natural outdoor conditions.

The solar water heating system may employ electric heater in the storage tank as an auxiliary source of heating, however performance of the system is evaluated under solar operation mode only.

This standard may also be applied to solar water heating systems employing unglazed/glazed solar flat plate collector, or any other non-concentrating design of solar collectors with appropriate benchmarking of performance parameters.

This standard does not apply to solar hot water systems employing concentrating solar collectors.

2 TEST SYSTEM

2.1 Requirement for the System Submitted for the Test

A complete set of domestic solar water heating system, designed to work on thermo-symphonic flow, shall be erected at the test site by the manufacturer/supplier in consultation with the testing laboratory. The system shall consist of a solar collector, a storage tank of appropriate capacity and piping to connect inlet and outlet of the solar collector to the storage tank. The piping may be insulated in accordance with the specifications of the systems marketed by the manufacturer. The testing shall be carried out on the system on an installed basis. Any deviation in the specifications may render test report invalid.

2.2 Specific Requirement of Tank for the Test

The tank of the system submitted with the system for testing should have inlet/outlet of 25 mm size and on 25 mm pipe opening at the top centre of the horizontal cylindrical tank for inserting resistance temperature detectors (RTD) sensor.

3 NOMENCLATURE

A_c = Gross area of solar collector, in m^2

A_a = Absorber area of solar collector, in m^2

A_p = Total outside surface area of the connecting pipes, in m^2

A'_p = Total outside surface area of pipes which may be effective for loosing heat during night-test, in m^2

A_s = Outside surface area of storage tank, in m^2

C_p = Specific heat of water, in J/kg K

F' = Collector efficiency factor

G_T = Solar irradiance on the inclined plane of the solar collector, in W/m^2

GT = Average value of solar irradiance on the inclined plane of the solar collector during day-test, in W/m^2

$(MC)_s$ = Thermal capacitance of the water in the storage tank only, in J/K

Q = Total energy collected by the solar collector during period of the day-test, in kWh

Q_c = Total solar radiant energy incident on the collector during day-test period, in kWh

t = Time, in s

T_a = Ambient air temperature, in °C

T_{ad} = Average ambient air temperature during day-test, in °C

T_{an} = Average ambient air temperature during night-test, in °C

T_m = Cold water temperature from mains, in °C

T_s = Temperature of water in storage tank, in °C

T_{sfn} = Final storage tank water temperature at the end of night-test, in °C

T_{sfd} = Final storage tank water temperature at the end of the day-test, in °C

T_{sid} = Initial storage tank water temperature at the start of the day-test, in °C

T_{sin} = Initial storage tank water temperature at the start of the night-test, in °C

$T_{sn,m}$ = Storage tank water temperature at mth interval during the night time, in °C

$\overline{U}_{sys,d}$ = Average overall heat loss coefficient of the system during day-test, in W/m^2 K

U_L = Overall heat loss coefficient of solar collector, in W/m^2 K

$\bar{U}_{sys,n}$ = Average overall heat loss coefficient of system during night-test, in W/m^2 K

U_p = Overall heat loss coefficient of piping, in W/m^2 K

U_s = Overall heat loss coefficient of storage tank, in W/m^2 K

Greek Symbol

Δt = Time duration of solar test, in s

$\bar{\eta}_{sys,o}$ = Maximum efficiency of the system averaged over the day-test period

$\bar{\eta}_{sys}$ = Efficiency of solar hot water system averaged over the day-test period

$(\tau\alpha)_{eff}$ = Effective transmittance–absorptance product of the solar collector for solar radiation

$\tau_{cooling}$ = Cooling time constant during night time test-period

Subcripts

a = Ambient conditions

c = Collector

d = Day time

f = Final value

i = Initial value

m = Mains, mth time

n = Night time

p = Pipe

s = Storage tank

T = On tilted collector surface

4 MEASUREMENTS

4.1 Physical Parameters

All physical measurements, such as, length, width, thickness, etc, shall be measured and reported, in mm. Gross area of solar collector is defined as the total area on which solar radiation is falling (taking into account the gap, if any, between the tubes, and also the frame, etc, of the ETC based system and of the collector box of the FPC based system). It shall be calculated by multiplying width and length of the collector measured from outer edge to the outer edge. For the solar water heating models using all-glass ETCs, length shall be measured from bottom side of the storage tank to the outer edge of bottom tube holder while width shall be taken as equal to the length of the bottom tube holder. The measurement accuracy of the gross area shall be ± 0.1 percent. The volume of the storage tank shall be measured to an accuracy of ± 1 percent.

4.2 Climatic Parameter

4.2.1 Solar radiation shall be measured using a Class I pyranometer on the plane parallel to the solar collector. For this, a separate mounting stand shall be used.

4.2.2 For measuring ambient air temperature, the measuring sensor (a calibrated RTD) shall be located shaded by a Stevenson screen in the vicinity of the test set-up (not more than 10 m from it). It shall be ensured that there is no obstruction by any structure or building to alter (block or enhance) the free flow of the natural wind to the sensor. The outside surface of the Stevenson screen shall be of light colour, preferably white, and its bottom shall be kept at least 1 m above the ground level.

4.2.3 The surrounding air speed shall be measured on the collector surface every 30 min with an accuracy of ±0.1 m/s and the average value of the day will be reported along with the test results.

4.3 Performance Parameter

4.3.1 The duly calibrated RTDs shall be used for measurement of water temperature. The accuracy of measurement shall be ±0.1°C or better. Measurements shall be made at three locations in the storage water tank. For this, measuring sensors shall be inserted through the opening provided by the manufacturer at the top centre of the tank. The sensors are placed at equal vertical distance from each one and from the top and bottom of the inner tank. The storage water tank temperature at any time t_{sm} shall be taken as mean of the temperature measured by the three RTD's.

4.3.2 The pressure shall be measured to an accuracy of 5 percent of actual reading.

4.3.3 Elapsed time measurement shall be made to an accuracy of ±0.2 percent. Computer based systems shall be used for data monitoring and logging. Analog or digital recorders shall have accuracy equal to or better than ±0.5 percent of the full-scale reading and have a time constant of 1s or less. The peak signal indication shall be between 50 percent and 100 percent of full scale.

5 SEQUENCE OF TEST

The test shall be carried out in the following sequence:

Sequence	*Test*
1	Pre-conditioning test
2	Static pressure leakage test
3	Thermal performance test (day time and night-time tests shall be performed one after another to complete one data set)

6 TEST PROCEDURES

6.1 Pre-Conditioning Test

6.1.1 Fully assembled system filled with water shall be kept exposed to weather conditions for 15 days having daily solar irradiance on the plane of solar collectors more than 16 MJ/m^2. The days with solar irradiance lesser than this value shall not be counted.

6.1.2 All parts of the system shall be inspected for any visual sign of degradation, deformation, ingress of moisture/dust, etc, and shall be reported.

6.2 Static Pressure Leakage Test

6.2.1 The purpose of this test is to ensure the integrity of solar hot water system particularly its tank to withstand the pressure, which it might meet in service. Schematic of test set-up for conducting this test is shown in Annex A.

6.2.2 Initially, air bleed valve is kept open and it is ensured that all air is removed from the collector by circulating water though it. Thereafter, the solar water heating system (Tank + Collector) is filled with water at a temperature of 60 ± 2 °C. After filling, the bleed valve and all other valves are closed, and a hydraulic pressure 0.5 kg/cm^2 is applied for flat plate collector system and a hydraulic pressure of 0.2 kg/cm^2 is applied for evacuated tabular collector system. The system is kept pressurized for a period of 30 min for both ETC and FPC system.

6.2.3 After 30 min, all parts of the system, especially the storage tank, shall be inspected for visual sign of any leakages. Results of the test in terms of the initial and final reading of the pressure gauge, temperature of the water, duration of the test and the result of inspection shall be reported.

7 THERMAL PERFOMANCE TEST

7.1 The test method is based on a lumped capacitance model, where it is assumed that average water temperature in the storage tank characterizes the behaviour of the whole system whether the storage is well mixed or stratified.

7.2 The test procedure envisages characterizing the thermal performance of the system without any withdrawal of hot water from the storage tank. This strategy is adopted because the performance of the solar water heating system strongly depends on the pattern of withdrawal of hot water from the storage tank, and there could be wide variation in the withdrawal pattern.

7.3 The system performance is evaluated in two parts corresponding to its performance during day time and separately during night time. Usually, the storage tank in solar water heating systems which are designed to work on the principle of thermosyphonic flow is located at higher level than the top edge of the solar collector with a view to suppressing reverse flow during night. In such a case, the solar collector and part of piping would not play role in loosing heat from the tank during night as it does during the day. However, night time test would account for all thermal losses from the system.

7.4 Day Time Performance

7.4.1 The following energy balance equation would determine the thermal performance of the solar hot water system during the day time:

$$\begin{bmatrix}\text{Rate of}\\ \text{change}\\ \text{in energy}\\ \text{contents of}\\ \text{the water in}\\ \text{the storage}\\ \text{tank}\end{bmatrix} = \begin{bmatrix}\text{Rate at which}\\ \text{useful energy}\\ \text{is supplied to}\\ \text{water in the}\\ \text{storagetank}\\ \text{by solar}\\ \text{collector}\end{bmatrix} - \begin{bmatrix}\text{Rate at which}\\ \text{energy is lost}\\ \text{from water in}\\ \text{the storage-}\\ \text{tank to the}\\ \text{ambient air}\end{bmatrix} \qquad \text{... (1)}$$

7.4.2 Mathematically, this may be expressed as follows:

$$(MC)_s \frac{dT_s}{dt} = A_a F' [G_T (\tau\alpha)_{eff} - U_L (T_s - T_a)] - (A_s U_s + A_p U_p)(T_s - T_a) \qquad \text{... (2)}$$

7.4.3 Rearranging and integrating equation (2) with respect to time, between the time period t_{1d} to t_{2d} during which the energy is collected, one gets

$$(MC)_s (T_{sfd} - T_{sid}) = A_a F' \int_{t_{1d}}^{t_{2d}} G_T (\alpha\tau)_{eff}.dt - (A_a F' U_L + A_s U_s + A_p U_p) \int_{t_{1d}}^{t_{2d}} (T_s - T_a)\, dt \qquad \text{... (3)}$$

7.4.4 The total energy incident on the collector during the time period from t_1 to t_2 is given by the following expression:

$$Q_S = A_c \int_{t_{1d}}^{t_{2d}} G_T \, dt \qquad \text{... (4)}$$

7.4.5 Dividing equation (3) by equation (4), one gets

$$\bar{\eta}_{sys} = \bar{\eta}_{sys,o} - \bar{U}_{sys,d}.\bar{X} \qquad \text{... (5)}$$

where

$$\bar{\eta}_{sys} = \frac{(MC)_s (T_{sfd} - T_{sid})}{A_c \int_{t_{1d}}^{t_{2d}} G_T dt} \qquad \text{… (6a)}$$

$$\bar{\eta}_{sys,\,o} = \frac{A_a F' \int_{t_{1d}}^{t_{2d}} G_T(\alpha\tau)_{eff}.dt}{A_c \int_{t_{1d}}^{t_{2d}} G_T.dt} \quad \ldots (6b)$$

$$\bar{U}_{sys,d} = \frac{A_a F' U_L + A_s U_s + A_p U_p}{A_c} \quad \ldots (6c)$$

$$\bar{X} = \frac{\int_{t_{1d}}^{t_{2d}} (T_s - T_a) dt}{\int_{t_{1d}}^{t_{2d}} G_T dt} \quad \ldots (6d)$$

The parameters $\bar{\eta}_{sys,\,o}$ and $\bar{U}_{sys,d}$ are defined as the characteristic parameters of the thermosyphonic solar water heating systems during the day test period.

7.5 Night Time Performance

7.5.1 During night time, no solar radiation is received and also there is no flow of water through the solar collector. The heat is therefore lost primarily from the storage tank and part of the piping. In view of this, the equation (3) may be re-written as follows:

$$(MC)_s \int_{t_{1n}}^{t_{2n}} \frac{dT_s}{T_s - T_a} = -(A_s\, U_s + A'_p\, U_p)\, dt \quad \ldots (7)$$

or

$$(MC)_s \ln\left[\frac{T_{sfn} - \bar{T}_{an}}{T_{sin} - \bar{T}_{an}}\right] = \bar{U}_{sys,n}\, .A_c(t_{2n} - t_{1n}) \quad \ldots (8)$$

where

$$\bar{U}_{sys,n}\, .A_c = (A_s\, U_s + A'_p\, U_p) \text{ and } t_{2n} - t_{1n} = 10 \text{ h} = 10 \times 3\,600 \text{ s} \quad \ldots (8a)$$

7.5.2 Cooling time constant to rate the performance of the solar water heating system during no-radiation period may be expressed by the following expression:

$$\tau_{cooling} = \frac{(MC)_s}{(\bar{U}_{sys,n}.A_c)} = \frac{1}{[t_{2n} - t_{1n}]} \ln\left[\frac{T_{sfn} - \bar{T}_{an}}{T_{sin} - \bar{T}_{an}}\right] \ldots (9)$$

Here, the $\tau_{cooling}$ represents the time at which the difference between the hot water temperature in the tank and the mean ambient temperature drops to 36.8 percent of its initial value.

8 TEST CONDITION

The total duration required for one cycle of the daytime test is 7 h, comprising 3.5 h before solar noon and 3.5 h after solar noon. The total solar irradiance during the test duration of 7 h shall be greater than or equal to 14 MJ/m^2. The ratio of solar irradiance in the forenoon and afternoon periods, each of 3.5 h, shall lie in between 0.5 and 1.5. The average value of wind speed during the test period shall be less than 4 m/s.

9 EXPERIMENTAL DETERMINATION

9.1 Thermal performance of the thermo-syphon domestic solar hot water system shall be characterized by three parameters namely $\bar{\eta}_{sys}, \bar{U}_{sys,d}$ and $\tau_{cooling}$ under this test procedure. The testing of the system shall be carried out in two steps, namely, the solar test (Day test) and the no-solar test (Night test). As the present test procedure proposes tests under conditions of no-load withdrawal, the performance thus obtained may be treated as the lower limit of the performance.

9.2 A schematic sketch of test-up is given in Annex A. The main components of the test set-up are as follows:

a) Domestic solar water heating system, as installed by the manufacturer, consisting of solar collector(s), storage tank, inter-connecting piping, and supporting stand.

b) A hydraulic loop integrated with the test set-up, consisting of a circulating pump (capacity > 40 litre/min) for mixing the water, one Rota meter to measure water circulation rate, a hydraulic pressure source, bleed valve, pressure gauge, and other accessories.

c) Measurement system, which shall include a computer based data logging systems, instruments/sensors for measuring solar radiation on the plane of solar collector, ambient air temperature in the vicinity of test set-up, air velocity on the plane of solar collector, and pressure gauge, along with necessary fixtures for their installation.

9.3 It shall be ensured that there is no shadow or obstruction to the solar radiation falling on to the solar collector or onto the Pyranometer during the period of day test. Also, all the piping including for hot water withdrawal, mixing pumps, etc, shall be insulated with 50 mm glass wool insulation with necessary cladding to protect it from moisture ingress, etc. Provision of cold water supply shall also be made.

9.4 Day time test shall be conducted in the following steps:

a) Determine Indian Standard Time (IST) corresponding to the solar noon.

b) Solar collector is shaded completely with an opaque cover, white on the top exterior, at about 4 h before the solar noon. The storage tank of the solar water heating system is filled fully with water. The quantity of water filled in the storage tank shall be taken as notional capacity of the solar water heating system.

c) The water in the storage tank is fully mixed by switching on pump for 5 min before beginning of the test at the designated time instant.

d) Initial value of the storage water temperature, T_{sid} is measured and recorded, and the shade-cover is removed at 210 min before the solar noon.

e) Measurements for ambient air temperature, water temperature of the storage tank, and solar irradiance on the plane of solar collector get commenced at the start of the test. The measurements are continued subsequently for the entire period of the test at an interval of 1 min or less, however, recording of data is adequate at an interval of 10 min.

f) To end the day-test cycle, the solar collector is again shaded on expiry of 210 min from solar noontime. The water in the storage tank is again mixed by operating the pump for 5 min and final storage water temperature (T_{sfd}) is measured and recorded.

g) The test is repeated for at least ten days with different values of initial storage water temperature. The first test shall be carried out with cold (supply) water in the storage tank. For subsequent days, initial water temperature shall be raised in uniform steps to cover up to 70°C (fully mixed storage).

h) Different initial temperature in the storage tank may be achieved by adding appropriate quantity of cold water to the previous day's heated water in the storage tank. Alternatively, hot water from any other source may also be used to achieve the required temperature of the water in the storage tank.

j) Data may be recorded in a format given at Annex B.

9.5 Night Time Test

Night time test essentially intends to find out overnight heat loss characteristics of the solar system. The duration of test is 10h under no-solar conditions. The following steps are undertaken to perform this test:

a) Measure the amount of solar radiation falling on the plane of solar collector(*s*) before starting the night-test; if the measured value is more than 50 W/m^2, cover the solar collector(*s*) by an opaque shield. This may be done by fixing the cover leaving a, gap of about 0.5 m above the solar collectors to allow free flow of surrounding air. After the solar radiation falls below the value of 50 W/m^2, the cover should be removed.

b) Switch on the mixing pump for about 5 min before the start of night test time so that water temperature in the storage tank is fully mixed and attains uniform temperature. Undertake measurement of initial storage water temperature, T_{sin}.

c) Carry out measurements of water temperature of storage tank, and ambient air temperature at an interval of 10 min during the test period.

d) Again, switch on the mixing pump at the end of test period of for about 5 min and measure final storage water temperature, T_{sfn}.

e) Repeat the experiments for number of days for which the test was performed.

f) Data may be recorded in a format given at Annex C.

9.6 Computation

9.6.1 Based on the measured data obtained during day-test and night-test, the characteristic parameters of the solar hot water system shall be evaluated as given subsequently.

9.6.2 Calculate $\bar{\eta}_{\text{sys}}$ from the following expression using data recorded during the day time test:

$$\bar{\eta}_{\text{sys}} = \frac{(MC)_{\text{s}}(T_{\text{sfd}} - T_{\text{sid}})}{A_c \int_{t_1}^{t_2} G_{\text{T}}\,\text{d}t} \qquad \text{... (11)}$$

9.6.3 The calculation of X involves integration of storage water temperature over the duration of daytime test, as is clear from equation (6d). For this, the test period is broken into m$^{\text{th}}$ intervals, each of 10 min, and piece wise integration is performed for each of the m$^{\text{th}}$ time interval using the following expression:

$$\bar{X} = \frac{\int_{t_{1d}}^{t_{2d}} (T_{\text{sd}} - T_{\text{ad}}).\text{d}t}{\int_{t_{1d}}^{t_{2d}} G_{\text{T}}\text{d}t}$$

$$= \frac{\sum_{m=1}^{42}\left(\frac{(\bar{T}_{\text{sfm}} + \bar{T}_{\text{sim}})}{2} - \bar{T}_{\text{adm}}\right) \times (t_{2\text{m}} - t_{1\text{m}})_{\text{d}}}{\sum_{m=1}^{42}\left(\frac{(G_{\text{Tfm}} + G_{\text{Tim}})}{2}\right) \times (t_{2\text{m}} - t_{1\text{m}})_{\text{d}}} \qquad \text{… (12)}$$

where $\bar{T}_{\text{adm}}$ represents average ambient temperature during the mth time interval; T_{sfm} and $\bar{T}_{\text{sim}}$ represents the water temperature of the three RTD's in the storage tank at the end and start of the mth time interval, respectively. Similarly G_{Tfm} and G_{Tim} are the solar irradiance value recorded at the end and at the start of the m_{th} time interval obviously, the value of $(t_{2m} - t_{1m})_d$ in the above expression is equivalent to 10 min.

9.6.4 Plot a curve with values of $\bar{\eta}_{sys}$ on y-axis and those of $\bar{X}$ on x-axis. Draw a trend line using regression method of least squares of curve fitting, and obtain for all the ten days values of $\bar{\eta}_{sys,o}$ and $\bar{U}_{sys,d}$ from the intercept of the trend line with y-axis and slope of the trend line respectively.

9.6.5 System efficiency corresponding to the following standard test conditions may be calculated using equation (5):

a) Average storage temperature = 50 °C

b) Average ambient air temperature during test period = 25 °C

c) Average of total solar radiation incident on the plane of solar collectors = 700 W/m^2

9.6.6 Amount of thermal energy stored in the storage tank during a period of 7 h corresponding to the standard test conditions, in kWh, may be calculated as follows:

$$Q = \bar{\eta}_{sys}\text{(corresponding to standard conditions)} \times A_c \times 0.7 \times 7 \quad \text{...(13)}$$

9.6.7 The value of $\tau_{cooling}$ can be calculated using equation (9). $\tau_{cooling}$ can also be calculated by plotting a straight line curve between $\ln\left[\bar{T}_{sn,m} - \bar{T}_{an}\right]$ *versus* time $t_{m,n}$. $T_{sn,m}$ is the storage tank water temperature at $t_{m,n}$ time thus obtained. The inverse of the slope of the trend line shall give $\tau_{cooling}$.

10 TEST REPORT

A test report shall be generated in the format given at Annex D.

ANNEX A

(*Clause* 6.2.1)

EXPERIMENTAL SET-UP

A-1 A schematic diagram of test set-up for conducting this test is shown below:

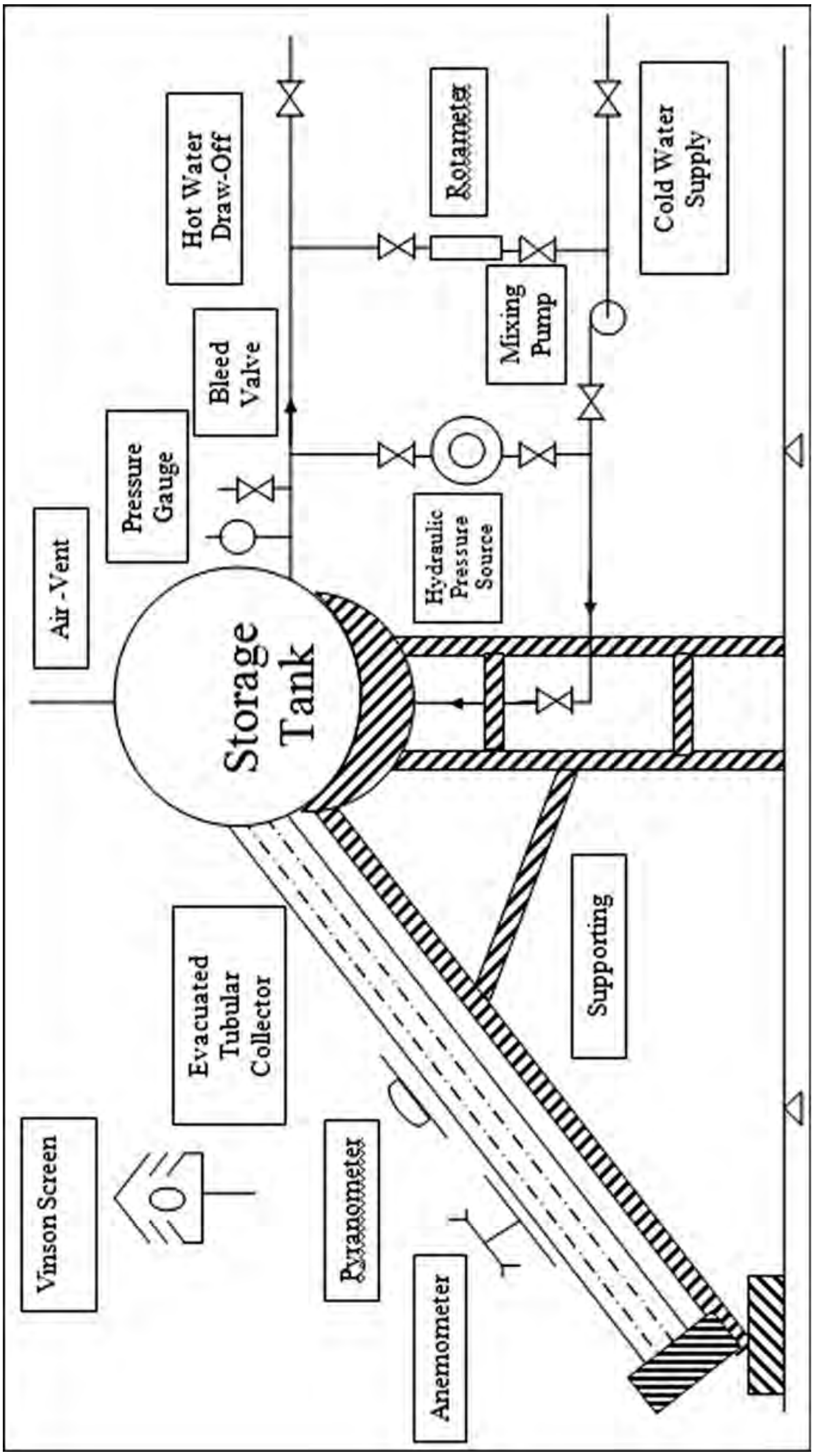

FIG 1 SCHEMATIC DIAGRAM OF THE EXPERIMENTAL SET-UP

ANNEX B

(*Clause* 9.4)

DAY TIME TEST

FORMAT TO RECORD TEST RESULTS

Time h	$\overline{T}_{ad}$ °C	$\overline{G}_T$ W/m^2	**Storage Water Temperature** °C				**Wind Speed** m/s
			Sensor 1	Sensor 2	Sensor 3	Average	
0000							
0010							
0020							
0030							
0040							
0050							
0100							
0110							
0700							

ANNEX C

(*Clause* 9.5)

NIGHT TIME TEST FORMAT TO RECORD TEST RESULTS

Time h	**Ambient Temperature** ºC	**Storage Water Temperature** ºC			
		Sensor 1	Sensor 2	Sensor 3	Average
0000					
0010					
0020					
0030					
0040					
0060					
0070					
1000					

ANNEX D

(*Clause* 10.1)

FORMAT FOR TEST REPORT

A	**GENERAL**		
a)	Name and address of manufacturer/supplier		
b)	Contact details of manufacturer/supplier		
c)	Details of sample submitted/model, if any		
d)	Latitude and longitude of test laboratory		a) Latitude: b) Longitude:
e)	Duration of the test		
B	**SPECIFICATION OF THE TEST SAMPLE** (All dimensions in mm, unless specified otherwise)		
1)	**Evacuated Tube Collector (ETC)**		
	a)	Make/Model	
	b)	Complete address of the manufacturer including e-mail/web site etc.	
	c)	Type (All glass direct flow/ Heat-pipe type/Any other (please specify)	
	d)	Tube length	
	e)	Inner diameter of inner tube	
	f)	Outer diameter of outer tube	
	g)	Number of tubes	
	h)	Details of selective coating (data from manufacturer may be used)	
	j)	Exposed area (gross) of a single Tube (Di L), m^2	
	k)	Gross aperture area of the collector, m^2	
	m)	Reflector below the tubes (Provided/Not provided)	
2)	**Flat Plate Collector**		
	a)	Box material	
	b)	Box length	
	c)	Box thickness	
	d)	Box width	
	e)	Absorber material	
	f)	Absorber thickness	
	g)	Absorber coating	
	h)	Insulation thickness (Back)	
	j)	Insulation thickness (Side)	
	k)	k-Value at 100° C ,$Wm^{-2}K^{-1}$	
	m)	BIS Certified (Yes/No)	
	n)	BIS Certificate No	Attach a copy

3)	**Storage Tank**		
	a)	Inner tank thickness and material	
	b)	Material and thickness of outer cladding	
	c)	Capacity (kg) (without taking into account water in the collector)	
	d)	Material and thickness of insulation: 1) Plane side of tank 2) Circular side of tank	
	e)	Height of hot water withdrawal point from bottom of the tank	
	f)	Height of cold water inlet point from bottom of the tank	
4)	**Connecting Pipes**		
	a)	Material	
	b)	Outer/inner diameter	
	c)	Outer surface coating	
	d)	Insulation material and thickness	
5)	**Supporting Stands/Frame**		
	a)	Material	
	b)	Type and thickness	
	c)	Outer surface coating	
C	**TEST RESULTS**		
a)	Pre-Conditioning test		
	Results of inspection after 15 days of test		
b)	Static Pressure Leakage Test		
	1)	Initial and Final Pressure (kg/cm^2)	
	2)	Temperature of water in the storage tank (°C)	
	3)	Duration of the test period (min)	
	4)	Results of inspection	Leakage observed /not observed
c)	Thermal Performance Test		
	1)	Percentage Maximum efficiency of the system, $\eta_{sys,o}$	
	2)	Overall heat loss coefficient of the system during day-time test, $U_{sys,d}$ (W/m²K)	
	3)	Night-time heat loss coefficient of the system, $U_{sys,n}$, (W/m²K) and $\tau_{cooling,n}$ (days)	
	4)	Percentage system efficiency at standard test conditions ($\overline{T}_S = 50°C, \overline{T}_{ad} = 25°C, \overline{G}_T = 700$ W/m²)	
	5)	Average amount of energy collected (Q) during the period of daytime test corresponding to standard test conditions (kWh)	
	6)	A table of the data points for day-time test along with values of wind speed (averaged over the test period).	Attached
	7)	A graph between X and η_{sys}	Attached
d)	Any Other Detail		
e)	Remarks		

Date:
Place:
(Testing officer) **(Head of the test laboratory)**

ANNEX E

(*Foreword*)

COMMITTEE COMPOSITION

Renewable Energy Sources Sectional Committee, MED 04

Organization	*Representative(s)*
Ministry of New and Renewable Energy, New Delhi	Dr B. Bandyopadhyay (***Chairman***)
Ankur Scientific Energy Technologies Pvt Ltd, Vadodara	Dr B. C. Jain Shri G. P. Nagori (*Alternate*)
Bipin Engineers Pvt Ltd, Pune	Shri H.S. Revankar Shri A. K. Baikerikar (*Alternate*)
Borosil Glass Works Ltd, Mumbai	Shri S. Das Gupta Shri Shreevar Kheruka (*Alternate*)
Central Arid Zone Research Institute, Jodhpur	Dr Piyush C. Pande
Central Public Works Department, New Delhi	Shri S. P. Barnwal Shri A. K. Goel (*Alternate*)
Centre for Wind Energy Technology, Chennai	Dr S. Gomathinayagam Shri A. Senthil Kumar (*Alternate*)
Consumer Coordination Council, Noida	Shrimati Ramaben R. Mavani Shri R. K. Kaplash (*Alternate*)
Directorate General of Meteorology, New Delhi	Dr R. D. Vashistha Shri M. K. Gupta (*Alternate*)
Emmvee Solar Systems Pvt Ltd, Bangalore	Shri Vijay Kumar C. R.
Gadhia Solar Energy Systems Pvt Ltd, Valsad	Shri Badal Shah
Gujarat Energy Development Agency, Vadodara	Shri K. V. Doshi Shri S. B. Patil (*Alternate*)
Indian Council of Agricultural Research, New Delhi	Shri S. K. Tandon Dr A. K. Dubay (*Alternate*)
Indian Institute of Technology, Mumbai	Shri J. K. Nayak Dr Shireesh B. Kedare (*Alternate*)
Indian Institute of Technology, New Delhi	Dr S. C. Mullick Dr T. C. Kandpal (*Alternate*)
Indian Renewable Energy Development Agency Ltd, New Delhi	Shri D. Majumdar
Karnataka Solar Manufacturers Association, Bangalore	Shri A. Palani
Maharashtra Energy Development Agency, Pune	Shri S. R. Chaudhari Shri H. M. Kulkarni (*Alternate*)
Maharashtra Solar Manufacturers Association, Pune	Shri Suhas Ghotikar Shri Mangal Akole (*Alternate*)
Ministry of New and Renewable Energy, New Delhi	Dr Ashvini Kumar Dr A. K. Singhal (*Alternate* I) Dr A. R. Shukla (*Alternate* II)
National Bank for Agriculture and Rural Development, Mumbai	Shri S. S. Rajshekhar Shri V. K. Trehan (*Alternate*)
Regional Test Centre, Pune	Dr M. G. Takwale
Regional Test Centre-Cum-Technical Backup Unit For Solar Thermal Devices, Indore	Dr S. P. Singh Dr R. N. Singh (*Alternate*)
Sardar Patel Renewable Energy Research Institute, Vallabh Vidyanagar	Dr S. Mohana Shrimati H. S. Desai (*Alternate*)
Solar Energy Centre, Gurgaon	Dr B. Bandyopadhyay Dr S. K. Singh (*Alternate*)
Solar Energy Society of India, New Delhi	Shri A. P. Shrivastava Shri Rajinder Kumar (*Alternate*)
Solchrome Private Ltd, Parwanoo	Shri K. K. Singla

Organization	*Representative(s)*
The Energy and Resources Institute, New Delhi	SHRI SHIRISH S. GARUD DR ISHAN PUROHIT (*Alternate*)
In personal capacity (*C-103A, JVTS Garden, Chatarpur Extension, New Delhi 110074*)	SHRI ATAM KUMAR
BIS Directorate General	SHRI C. K. VEDA SCIENTIST 'F' and Head (MED) [Representing Director General (*Ex-officio*)]

Member Secretary
SHRI M. K. PARAMANIK
Scientist 'C'(MED), BIS

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This Indian Standard has been developed from Doc No.: MED 04 (1050).

Amendments Issued Since Publication

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Published by BIS, New Delhi